Instrument Response Modeling and Simulation for the GLAST Burst Monitor

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Abstract. The GLAST Burst Monitor (GBM) is designed to provide wide field of view observations of gamma-ray bursts and other fast transient sources in the energy range 10 keV to 30 MeV. The GBM is composed of several unshielded and uncollimated scintillation detectors (twelve NaI and two BGO) that are widely dispersed about the GLAST spacecraft. As a result, reconstructing source locations, energy spectra, and temporal properties from GBM data requires detailed knowledge of the detectors' response to both direct radiation as well as that scattered from the spacecraft and Earth's atmosphere. This full GBM instrument response will be captured in the form of a response function database that is derived from computer modeling and simulation. The simulation system is based on the GEANT4 Monte Carlo radiation transport simulation toolset, and is being extensively validated against calibrated experimental GBM data. We discuss the architecture of the GBM simulation and modeling system and describe how its products will be used for analysis of observed GBM data. Companion papers describe the status of validating the system.

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GBM INSTRUMENT RESPONSE ARCHITECTURE

Because the GLAST Burst Monitor (GBM) consists of semi-independent detectors distributed about the GLAST spacecraft, scientific use of its data requires detailed understanding of the response of the detectors to all paths of radiation—including radiation that interacts directly in the detectors, scatters in the GLAST spacecraft, scatters in the earth's atmosphere, or interacts through a combination of paths. Generation of science data products such as gamma-ray burst energy spectra and sky locations depends critically on the ability to accurately model this complex system—the details of which will be captured in an overall GBM instrument response function. To model this function we use a combination of Monte Carlo computer simulation and modeling techniques that incorporate, and are verified against, experimental calibrations. Monte Carlo simulation provides the physical, idealized, response, while the incorporation of calibration results provides for non-ideal instrumental effects.

The GBM simulation and detector response (SIMDRM) project falls under the GBM Instrument Operations and Data Analysis (IODA) program since all elements of data analysis must incorporate detector response data products. A primary task of the project is development of the GBM Response Simulation System (GRESS)—a comprehensive collection of computer models, simulation software, and data packaging tools. The GRESS package includes facilities for (1) physical simulation through a modified[1] GEANT4[2] toolkit architecture, (2) custom instrumental effects simulators, (3) custom data packagers, and (4) interfaces to GBM IODA data processing/analysis software.

Because of vastly differing scale size, GRESS separates the total GBM instrument response into two components: the "direct" detector + spacecraft response and the atmospheric scattered response. The direct

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component of the GBM response captures the physical and instrumental response of the detectors + spacecraft combined system. It incorporates a detailed mass model of the GLAST observatory, including the GBM detectors, the Large Area Telescope, and all in-flight spacecraft components (see Figure 1). Unlike many earlier space-borne gamma-ray instrument response simulation efforts (e.g., BATSE[2], COMPTEL, etc.), GRESS captures the combined response rather than separating detector simulations from passive spacecraft elements. This is because the GLAST spacecraft is highly non-uniform in its scattering properties and the GBM detectors are embedded in this non-uniformity. In practice, the direct response as a function of photon energy and direction will be captured in a "Direct Response Matrix" (DRM) database, including results from individual simulation runs at an array of incident source directions. Snapshots at specific incident photon energies from a preliminary DRM database are shown in Figure 1.

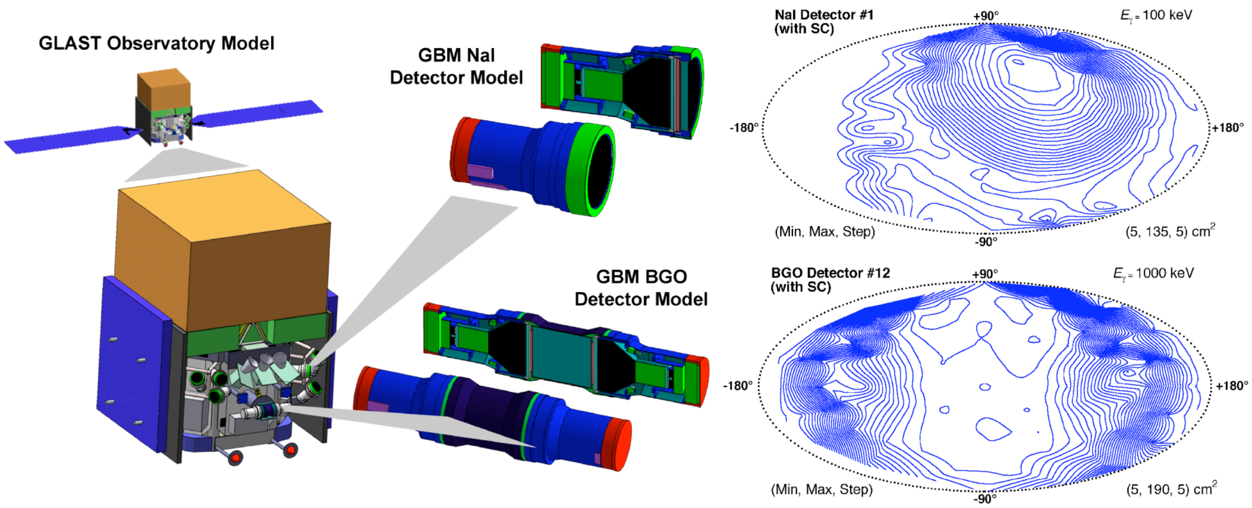

FIGURE 1. *Left:* Mass models of the GLAST observatory used for GBM instrument response simulations. *Right:* Preliminary GBM "direct" response as a function of sky direction for a single NaI (top) and a single BGO (bottom) detector at specific energies (LAT pointing axis is at latitude = 90°). The full DRM database will capture this information for all energies and angles.

The atmospheric scattered response is independently estimated through simulating photon scattering in a shell-based atmosphere model. The resulting scattered photons are collected at a virtual boundary representing the spacecraft altitude, and their properties captured in a five-dimensional Atmospheric Response Matrix (ARM). For a particular set of Earth-spacecraft viewing conditions, the DRM and ARM databases are combined to form a source-specific total response function. This is accomplished by the IODA "DRMGEN" software that will run in a stand-alone mode (e.g., for analyzing the spectrum of a burst with known location) or as an integrated part of the joint spectral/spatial burst location software (where direction-specific response must be evaluated "on the fly" for each trial burst location). Source-specific response functions will be generated and distributed as routine science data products for all gamma-ray bursts that are detected with GBM.

Each element of the GBM SIMDRM architecture is being validated—against experimental data in the case of the direct response[4,5,6] and against previous BATSE simulation results[3] in the case of the atmospheric response. These validations will ensure that the resulting response functions represent a reasonable reflection of the true GBM system.

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